# Why the observed jet quenching at RHIC is due to parton energy loss

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More than a decade after the original proposal of jet quenching due to radiative parton energy loss, conclusive experimental evidence has been found in central $Au+Au$ collisions at the Relativistic Heavy-ion Collider (RHIC) not only from the suppression of high-$p_T$ single inclusive hadron spectra but also the suppression of back-side jet-like correlations. The latter provides direct evidence for medium modification of the parton fragmentation functions. More recent results of $d+Au$ collisions further prove that the observed jet quenching is due to final-state interactions with the produced medium. Initial-state scatterings in cold nuclei only broaden the initial transverse momentum, leading to the Cronin enhancement of intermediate high-$p_T$ hadron spectra as was first predicted for $p+A$ collisions at RHIC.

The original proposal of jet quenching in a dense (or normal) nuclear medium was based on the idea that radiative energy loss during the propagation of an energetic parton must suppress the leading hadron distributions inside a jet. This leads to medium modification of the jet fragmentation functions and suppression of the high-$p_T$ hadron spectra in high-energy heavy-ion collisions. Such medium-induced radiative parton energy loss has since been studied in detail and in many different approaches in QCD that include the non-Abelian Laudau-Pomerachuck-Migdal (LPM) interference effect. The energy loss was found to be proportional to the gluon density of the medium. It was further predicted that jet quenching due to parton energy loss should also lead to the azimuthal anisotropy of high-$p_T$ hadron spectra in non-central heavy-ion collisions, which has been observed at RHIC.

Phenomenological studies of hadron spectra based on parton energy loss have found that the observed suppression of high-$p_T$ single hadron spectra implies large parton energy loss or high initial gluon density. The same parton energy loss is also found to reproduce the observed suppression of back-side correlation and the high-$p_T$ azimuthal anisotropy. Most importantly, the calculated centrality dependences of the suppression of both single hadron spectra and back-side correlation agree very well with the experimental measurements. The deduced initial gluon density at an initial time $\tau_0 = 0.2$ fm/$c$ is found to be about 30 times of that in a normal nuclear matter. If the transverse energy per particle is 0.5 GeV, the above gluon density will correspond to an initial energy density of $\varepsilon = 15$ GeV/fm$^3$, which is about 100 times of the energy density in a cold nuclear matter. In addition, the measured large azimuthal anisotropy for soft hadrons is found to saturate the hydrodynamic limit. These experimental results all point to an initial medium that is strongly interacting and has a large initial pressure gradient. Within our current understanding of QCD, such a strongly interacting medium with about 100 times normal nuclear energy density can no longer be a normal hadronic matter.

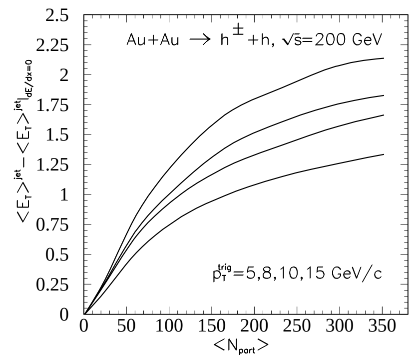


FIG. 1: The average energy loss for partons that produce a final hadron with $p_T^{\rm trig}$ in $Au+Au$ collisions.

The aforementioned analyses of RHIC data on jet quenching are all based on a picture in which partons propagating through the dense medium lose energy first and then hadronize outside in the same way as in the vacuum. It is reasonable to ask whether leading hadrons from the jet fragmentation could have strong interaction with the medium and whether hadron absorption could be the main cause for the observed jet quenching. This paper [1] will provide arguments against such a scenario in detail and list experimental evidence that the observed patterns of jet quenching in heavy-ion collisions at RHIC can *only* be the consequences of parton energy loss, not hadronic absorption.

A direct measurement of parton energy loss is also proposed which requires the reconstruction of the total energy of a jet that has a triggered hadron with a fixed value of $p_T^{\rm trig}$. The difference between $Au+Au$ and $p+p$ measurements (plus $p_T$ broadening due to initial multiple parton scattering) should be related to the averaged total energy loss for the jet whose leading parton produces the triggered hadron after energy loss, as shown in Fig. 1. The measurement of softening of the effective hadron-triggered fragmentation function will further detail the pattern of energy loss and induced gluon emission. The importance of jet quenching studies at lower RHIC energies is also discussed.

[1] X.-N. Wang, Phys. Lett. **B579**, 299 (2004), nucl-th/0307036.